Question	Marking guidance	Mark	AO	Comments
04.1	Bonds broken = 2(C=O) + 3(H–H) = 2 × 743 + 3 × H–H Bonds formed = 3(C–H) +(C–O) + 3(O–H) = 3 × 412 + 360 + 3 × 463 –49 = [2 × 743 + 3 × (H–H)] – [3 × 412 + 360 + 3 × 463]	1	AO1b	Both required
	3(H–H) = –49 – 2 × 743 + [3 × 412 + 360 + 3 × 463] = 1450	1	AO1b	Both required
	H–H = 483 (kJ mol^{-1})	1	AO1b	Allow 483.3(3)
04.2	Mean bond enthalpies are not the same as the actual bond enthalpies in CO_2 (and/or methanol and/or water)	1	AO1b	
04.3	The carbon dioxide (produced on burning methanol) is used up in this reaction	1	AO3 1b	
04.4	4 mol of gas form 2 mol	1	AO2f	
	At high pressure the position of equilibrium moves to the right to lower the pressure / oppose the high pressure	1	AO3 1b	
	This increases the yield of methanol	1	AO3 1b	
04.5	Impurities (or sulfur compounds) block the active sites	1	AO1b	Allow catalyst poisoned

04.6	Stage 1: moles of components in the equilibrium mixture $CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$ Initial moles: 1.0 3.0 0 0 Eqm moles: (1–0.86) = 0.14; (3-3×0.86) = 0.42; 0.86; 0.86	1	AO2f	Extended response question
	Stage 2: Partial pressure calculations Total moles of gas = 2.28	1	AO2f	
	Partial pressures = mol fraction × p_{total} p_{CO2} = mol fraction × p_{total} = 0.14 × 500/2.28 = 30.7 kPa p_{H2} = mol fraction × p_{total} = 0.42 × 500/2.28 = 92.1 kPa	1	AO2f	M3 is for partial pressures of both reactants Alternative M3 = pp_{CO2} = 0.0614 × 500 pp_{H2} = 0.1842 × 500
	p_{CH3OH} = mol fraction × p_{total} = 0.86 × 500/2.28 = 188.6 kPa p_{H2O} = mol fraction × p_{total} = 0.86 × 500/2.28 = 188.6 kPa	1	AO2f	M4 is for partial pressures of both products Alternative M4 = pp_{CH3OH} = 0.3772 × 500 pp_{H2O} = 0.3772 × 500
	Stage 3: Equilibrium constant calculation $K_p = p_{CH3OH} \times p_{H2O} / p_{CO2} \times (p_{H2})^3$	1	AO2f	
	Hence K_p = 188.6 × 188.6 / 30.7 × $(92.1)^3$ = 1.483 × 10^{-3} = 1.5 × 10^{-3}	1	AO1b	Answer must be to 2 significant figures
	Units = $\underline{kPa^{-2}}$	1	AO2f	